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The Harrison M. Randall
Laboratory of Physics

30 August 1988

Leon Lederman
Director
FERMI NATIONAL ACCELERATOR LABORATORY
Batavia, IL 60510

Dear Leon,

A group of us at Michigan are working to develop high-rate fast gas calorimetry and electronics suitable for a high luminosity SSC experiment; a module should be ready to test in about 10 months. We request the use of a FERMILAB testbeam to prove the concepts and implementation.

A copy of our request for Generic SSC Detector R&D Funds is attached. We have developed fast PWC cells for an electromagnetic calorimeter. We intend to use existing electronics to evaluate its performance. We expect to have an ambitious high tech electronics system ready for test somewhat later, and given success would be looking for a high-rate (10**8-10**9) beam to challenge the system.

We are seeking a test beam with 50-200 GeV protons or pions, some component of electrons, and some means to tag them such as a Cerenkov counter. We would request support of a PDP 11 MULTI based data logging system with BISON BOX, CAMAC crate, and magnetic tape or data link to the VAX cluster. We need PREP support mostly at the level needed to instrument and run the beam line, but including a powered NIM bin, 2 scaler modules, a CAMAC ADC module, 8 discriminators, 6 logic functions, and a gate module; the older LeCroy technology would be fine.

We would like to work on the test beam 2 to 6 shifts a week spread over at least a six month period; a control time estimate would be about 200 hours. Our calorimeter module will be on a table such that it can be moved or lowered out of the beam quickly and expeditiously. We would like our part of the CAMAC crate (8 slots) and our NIM bins to be exclusively for us.

Questions can be addressed to R. Thun (313-936-0792) or R. Gustafson (313-936-0812) at the University of Michigan; or by Decnet MICH::THUN or MICH::GUSTAFSON. We are available to help set up/implement the beam line.

Regards,

R. G.
Rudi Thun

Dick Gustafson
Rudi Thun

UM – HE – 88 – 18
August 31, 1988

Proposal to Develop SSC Detectors Based on Small-Diameter, Fast-Drift Proportional Tubes.

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Abstract

We propose to construct, instrument and test a fine-grained electromagnetic calorimeter based on small-diameter proportional tubes with maximum drift times of about 20 nsec. Construction of the calorimeter and configuration with existing electronics will be completed within one year. Development of specialized, fast, radiation-hard electronics will require somewhat more time. We request $140,400 for this project of which $101,250 is to be allocated for the required electronics R&D. We propose to test the calorimeter in a Fermilab test beam.

I. Introduction

One of the great challenges posed by the Superconducting Super Collider (SSC) is the enormous event rate (10^8 Hz). Such a rate produces event pile-up with most of the commonly used detector techniques. For example, typical gas-based drift chambers as well as liquid-based calorimeters involve signal collection times of order several hundred nanoseconds or more. The corresponding electronic gates used in the trigger and data collection will necessarily involve the overlap of tens of events when using such detectors. The problem of extracting the hidden physics jewels in the general debris of hadronic collisions is well known. One would, therefore, like to eliminate any additional problems from event pile-up. It is sometimes remarked that such pile-up only involves the overlay of minimum-bias events with a transverse energy so low as not to corrupt the interesting physics. However, the rate of random coincidences scales directly with the duration of the trigger gates. For example, two randomly coincident jet-jet events will enter the 4-jet sample and it is not obvious how easily such background events are rejected in the off-line analysis.

It is clear that ideally one would like to reduce the jitter in signal-collection times to the order of 1/EVENT RATE $\sim$ 10 ns. Shorter times yield little additional advantage since finite detector sizes introduce a jitter of that order just from variations in signal traversal times.

We propose to develop proportional-wire detectors with short ($\lesssim$ 20 ns) signal collection times. Specifically, for our first detector we plan to construct a prototype of a fine-sampling electromagnetic calorimeter which could be used for the simultaneous measurements of energy and particle direction. Such a detector might find application in the interior of a large muon-oriented spectrometer. Although we necessarily pick a specific prototype detector, what we will learn will have broad "generic" applicability to any tracking or calorimetric device based on fast proportional tubes.

II. Summary of Research Already Completed at Michigan

Through a "redirection of effort" (made possible in part by the slow turn-on of SLC) we have started a program of research at Michigan to find parameters suitable for SSC proportional chambers. This program has focussed so far on two topics: a search for gasses with high drift velocities and a study of the effects of neutrons on the operation of proportional chambers. The initial part of this work is documented in the attached preprint which has been accepted for publication in Nucl. Inst. and Methods. The main result of this paper is that maximum drift times as low as 16 ns are achievable with 4 mm wide proportional tubes operating with mixtures of HRS gas (89% Ar - 10% CO_2 - 1% CH_4) and CF_4. We have extended this work to a wide variety of other gas mixtures as shown in Figures 1 thru 4. Particularly promising are Ar - CO_2 mixtures which show drift velocities approaching those of the HRS - CF_4 mixtures.

We have also made a study of the effect of neutrons on proportional tube performance as a function of chamber gas. Our interest here is to understand the so-called "Texas Tower" effect observed in the Fermilab CDF experiment where occasionally very large pulses are observed inside a wire-chamber calorimeter. It is thought that the effect is primarily due to elastic scattering of $\sim$ 1 MeV cascade neutrons with hydrogen protons in the chamber gas and structure. The slow recoil protons are heavily ionizing and can leave a signal equivalent to several hundred minimum-ionizing particles. To test this hypothesis we exposed a chamber to a 925 mCi Am-Be source which yields approximately 2 x 10^6 neutrons per second with an energy spectrum from 1 to 5 MeV. The neutrons were moderated somewhat by several cm of paraffin. Gamma rays from the $\alpha + Be \rightarrow C^* + \mathrm{n}$ reaction were absorbed with 1.3 cm of lead placed between the chamber and source. Preliminary data, displayed in Figures 5 & 6, show a definite increase in the rate of large chamber pulses when increasing the hydrogen content of the gas. Fortunately both CO_2 and CF_4 are quenching gasses with large drift velocities and no free protons.

The members of our group involved in the construction of the L3 hadron calorimeter have also studied the effect of neutrons, and were among the first to demonstrate that neutrons, and specifically the large recoil proton pulses, were a major part of the uranium calorimeter "compensation." By using gasses with varying amounts of hydrogen in a test beam at CERN it was possible to vary the π/e ratio from about 0.8 to well above 1 for a test uranium - PWC calorimeter.

III. Prototype Detector

The original motivation for the work discussed in Section II came from a consideration of how to instrument the absorber of a muon spectrometer (see Figure 7) to allow the measurement of isolated electrons and of hadronic energy flow. The requirement of fast, radiation-hard detectors led to the idea of using small proportional tubes with fast gasses and operated at low gain (10^3-10^4). A geometry for implementing a calorimeter based on such tubes is sketched in Figure 8. The calorimeter is built up with planes containing alternating tubes and radiators placed transversely to the beams in a coaxial cylindrical stack. The planes are oriented in varying directions to create a fairly homogeneous calorimeter with a response that is essentially independent of the longitudinal position of the proton-proton collision point and independent of particle angle. Each plane yields a spatial coordinate of the shower so that the calorimeter can be used for both the track and energy measurements of showering particles. By running at a suitably low gain the calorimeter can be made insensitive to minimum-ionizing tracks and low-energy photons while being obviously sensitive to showering particles with "interesting" energies ($E \gtrsim 100$ GeV).

We propose to build a prototype calorimeter suitable for test beam use. As shown in Figures 9 and 10 the prototype consists of a stack of square planes oriented in a repeating series of $0° - 45° - 90° - 135°$ sets. Each plane consists of alternating tubes and radiators with a width of about 4 mm. We have not yet decided between lead and tungsten as the radiator material. For lead a radiation length is 0.56 cm and the Moliere radius is 1.6 cm while for tungsten the values are 0.35 cm and 0.92 cm respectively. Tungsten yields more compact showers but is therefore also more sensitive to the granularity of the calorimeter. The prototype calorimeter will be made about 30 radiation lengths deep and will contain of order 600 proportional tubes.

IV. Existing Electronics

We have available to us at Michigan several systems of charge digitizing electronics for chambers. These are available immediately; we have the operational experience to believe they can be set up expeditiously and used with no surprises.

The first system, designed and built by Ball, Gustafson, Longo, and Roberts, is composed of 8-channel cards, a controller-processor powering, reading and digitizing up to 255 channels, and a CAMAC interface reading up to 256 controllers. The card channel density is one per inch on a 3" x 8" card. Digitization is 12 bit (4096 with a sensitivity of about 2 femtocoulombs per count; pedestals are at about channel 100). There is a high impedance version with noise sigma of about 1 channel (2 femtocoulombs). A low impedance (25 ohm) version for possible charge division has a noise of 3 channels (12 femtocoulombs). A test charge injection calibration scheme is included. A gate is applied to the controller about 0.7 microseconds after the event passage; the effective gate width is about 2 microseconds. Digitization requires 25 microseconds per channel with controller operating in parallel. A sparse scan system is included. Readout of the controllers proceeds at CAMAC speeds.

8500 channels of the high impedance system were used in FNAL E613 at a cost of about $7/channel. A current inventory of available units shows at least 1000 channels with 7 controllers, and a CAMAC interface.

The low impedance system, designed and built by R. Gustafson, is also available. This consists of 12" boards, 3/8" per channel, 32 channels per board, with 25 ohm input impedance and, a gate time of 120 nanoseconds. Forty-two working boards exist. There are onboard delay lines which delay and clip the integrated charges; the gate signal is applied 450 nanoseconds after the input charge. The charge sensitivity is 4 femtocoulombs per channel with a noise sigma of 3 channels. The readout, control, and calibration systems are the same as for the slower system and the components can be mixed. This system ran in FNAL E711.

These systems require a conventional CAMAC crate based data acquisition system. A PDP 11 based MULTI system with BISON box and magnetic tape logging would be adequate.

A third system consists of 1000 channels of conventional LeCroy FASTBUS ADCs which are presently available. Characteristics are 50 femtocoulomb/count, 50 ns minimum gate, 15 bits, 96 channel per board, 300 microsecond conversion time, and a readout rate of 7 megaword/sec. A computer based data acquisition system with a fastbus interface would be required. Alternately the system could be read out through CAMAC.

V. New, Fast Electronics

The existing electronics, though acceptable for detector studies, are not usable in a high rate environment. For the SSC, one would like to implement fast electronics in high density, radiation hardened integrated circuits that can be manufactured at low item costs. We propose to pursue this goal with the help of the newly established University of Michigan integrated circuit laboratory associated with the Engineering School. We have acquired two CAD stations that are network linked to the Engineering School and execute the same design and simulation software used there. We also have a staff engineer, Maher Siraj, who is familiar with the software and procedures of the Engineering School. He will undertake the electronics development.

The starting point for this development will be the fast pulse designs developed by Radeka[1]. These circuits provide clipped and shaped pulses of less than 10ns. The fabrication of these bipolar circuits using indium contacts to silicon wafer based interconnects looks promising for compactness and flexibility. The resistance of the complete package to neutrons and ionizing radiation will be evaluated with the help of the University of Michigan Phoenix reactor where fluxes of neutrons from modest to very intense exposures are available. Bipolar circuits are noted to be subject to permanent damage from neutrons.

A promising alternate approach is to use the fastest available MESFETs. These circuits are less sensitive to neutron damage and can be constructed with higher densities. They are known to suffer temporary disturbances in their insulating layers due to ionizing radiation but this sensitivity has been reduced in recent years. If circuits of sufficient speed can be designed and simulated using this technology, prototypes will be constructed and their performance and radiation resistance to ionizing radiation tested.

Attention will be directed to providing for local fast signal processing in the design of the front-end electronics. This will hopefully provide entry for the development of hierarchical trigger processing in the future should the proposed detector and electronics scheme prove effective and sufficiently radiation resistant. Test readout of the fast electronics will utilize the FASTBUS ADCs mentioned above.

VI. Test Beam

We are requesting the use of a FERMILAB test beam for testing the calorimeter module. We hope to determine basic operating characteristics about one year from now, and then to move into a high rate test behind some running experiment. We append a copy of the test beam proposal letter to FNAL. We expect to adapt our existing electronics to test the calorimeter in a modest rate environment with a 50-200 GeV beam containing hadrons and electrons. The high rate tests will use the new electronics to cope with the pile up and rate problems, and the realities of high chamber currents.

VII. Radiation Test Facility

A major type of radiation for the detectors environment is expected to be neutrons in the neighborhood of 1 MeV. For a detector situated at 2 meters from the interaction of the neutron fluence is expected to be of the order of 2 x $10^{12}/\text{cm}^2/\text{yr}$.

The University of Michigan Phoenix Nulcear Reactor can provide a test facility for us to expose PWCs and/or electronics, powered or unpowered. Packages of 2" diameter and up to 20" long can be exposed to fluences of between 3 x 10^8 and 2 x 10^{12} neutrons (> 1 MeV)/cm^2/sec. (The package should be somewhat shorter to keep the dosage reasonably uniform over the package.) The staff of the reactor have expressed their willingness to cooperate with us in this effort.

VIII. Time Scales

Our intention is to have the prototype calorimeter ready by the summer of 1989. Existing electronics will be collected and reconfigured for this prototype on the same time scale. Measurements in a test beam would be conducted during the second half of 1989, the exact time depending on the availability of a suitable test beam.

The time scale for the development of new, fast electronics is more difficult to predict because of the more fundamental R & D effort required for design and fabrication. The goal would be to have such electronics ready by the end of 1989.

IX. Budget

The budget for this project is divided into four major areas:

1.) Fabrication of prototype calorimeter

a.) Materiel $ 4,000.00

b.) Machining and assembly $ 8,000.00

2.) Reconfiguration of existing electronics (including new cables and connectors) $ 9,000.00

3.) Travel to test beam and operational funds (gas, plumbing, etc.) $ 6,000.00

4.) Reactor access fee $ 2,000.00

5.) R & D and fabrication of new, fast electronics

a.) Prototype mask and IC supplies	\$ 30,000.00
b.) Electronics Shop charges	\$ 20,000.00
c.) IC Laboratory fees	\$ 15,000.00
d.) Computer design and simulation costs	\$ 10,000.00
Total direct cost	\$104,000.00
35% MTDC (indirect costs)	\$ 36,400.00
TOTAL	\$140,400.00

X. Manpower and Responsibilities

The responsibilities for this project are divided as follows:

1.) Design and fabrication of calorimeter - R. Thun

2.) Reconfiguration of existing electronics - R. Gustafson, B. Roe, R. Ball

3.) Test beam set-up - R. Gustafson

4.) New electronics - J. Chapman

5.) Test beam measurements - all

XI. References

1.) J. Fischer, et al., NIM A238 (1985) 249

Figures

1.) Drift-time distributions from the traversal of cosmic rays through 4 mm wide proportional tubes. Distributions are for various Ar- CO_2 mixtures.

2.) Fe^{55} spectra for various Ar-CO_2 mixtures.

3.) Drift-time distributions for various Ar-CO_2-CF_4 mixture in the 4 mm proportional tubes.

4.) Drift time distributions for pure quenching gasses in the 4 mm proportional tubes.

5.) Pulse height spectra from a drift chamber exposed to an Am-Be source as a function of lead absorber between chamber and source. The lead absorbs gamma rays which yield counts at low pulse height. The lead has no effect on counts with large pulse height which are generated by neutron-proton elastic scattering.

6.) Pulse height spectra from a drift chamber exposed to an Am-Be source as a function of various gas mixtures. For each mixture, the voltage was chosen to give equal gain as determined with an Fe^{55} source. As the hydrogen content of the gas is increased, a significant increase of counts with large pulse height is observed. This presumably originates from neutron-proton elastic scattering.

7.) Possible detector lay-out for a muon spectrometer. A major challenge is the instrumentation of the absorber to measure electron and hadronic jet energies.

8.) A possible geometry for an electromagnetic calorimeter inside the absorber of the muon spectrometer.

9.) Prototype electromagnetic calorimeter. Each layer consists of alternating proportional tubes and radiator (either tungsten or lead).

10.) Orientation of layers in the prototype calorimeter. The sequence is a repeating set of $0° - 45° - 90° - 135°$ orientations.

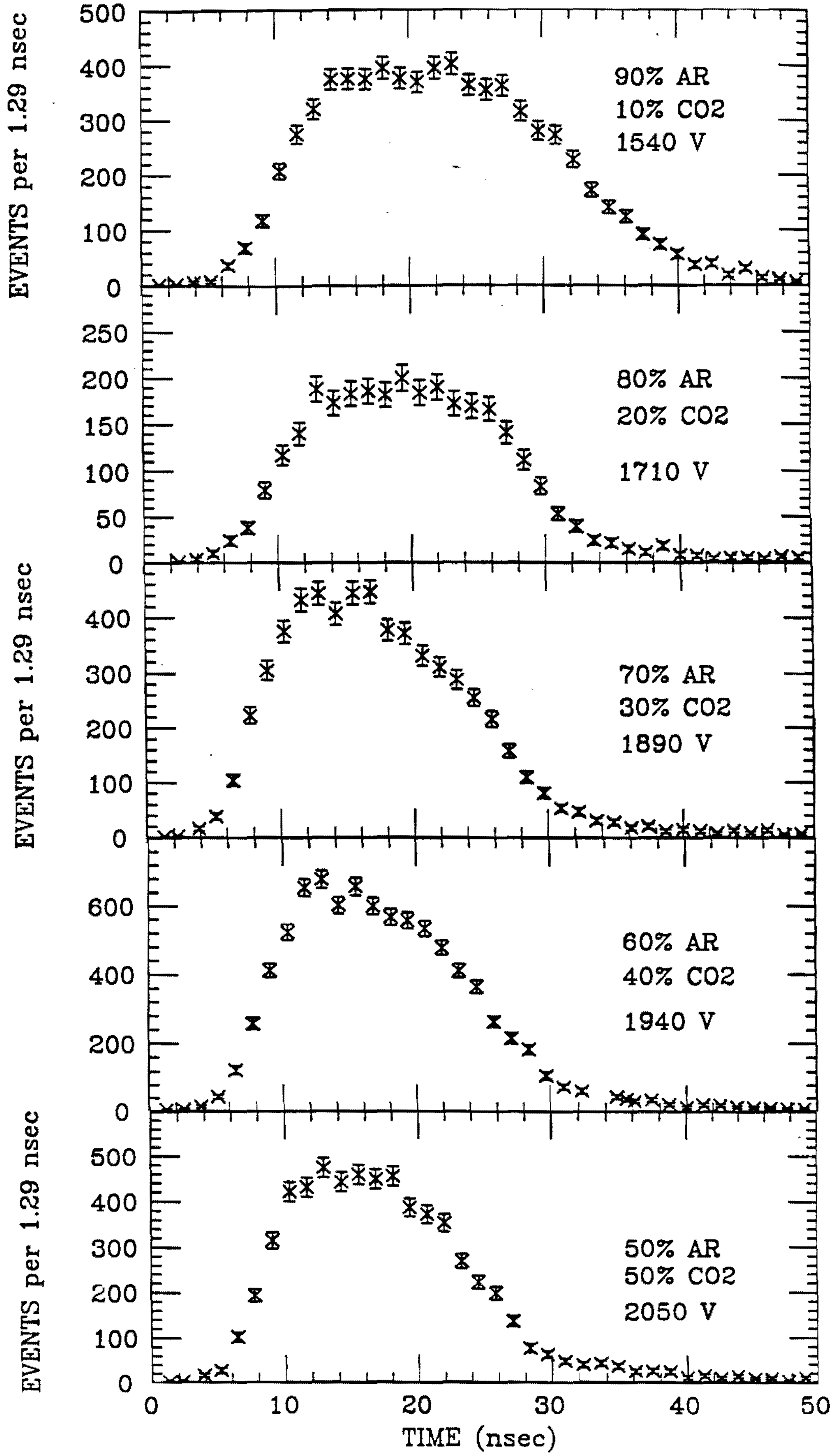

EVENTS per 1.29 nsec
90% AR
10% CO2
1540 V
80% AR
20% CO2
1710 V
70% AR
30% CO2
1890 V
60% AR
40% CO2
1940 V
50% AR
50% CO2
2050 V
TIME (nsec)

FIG. 1

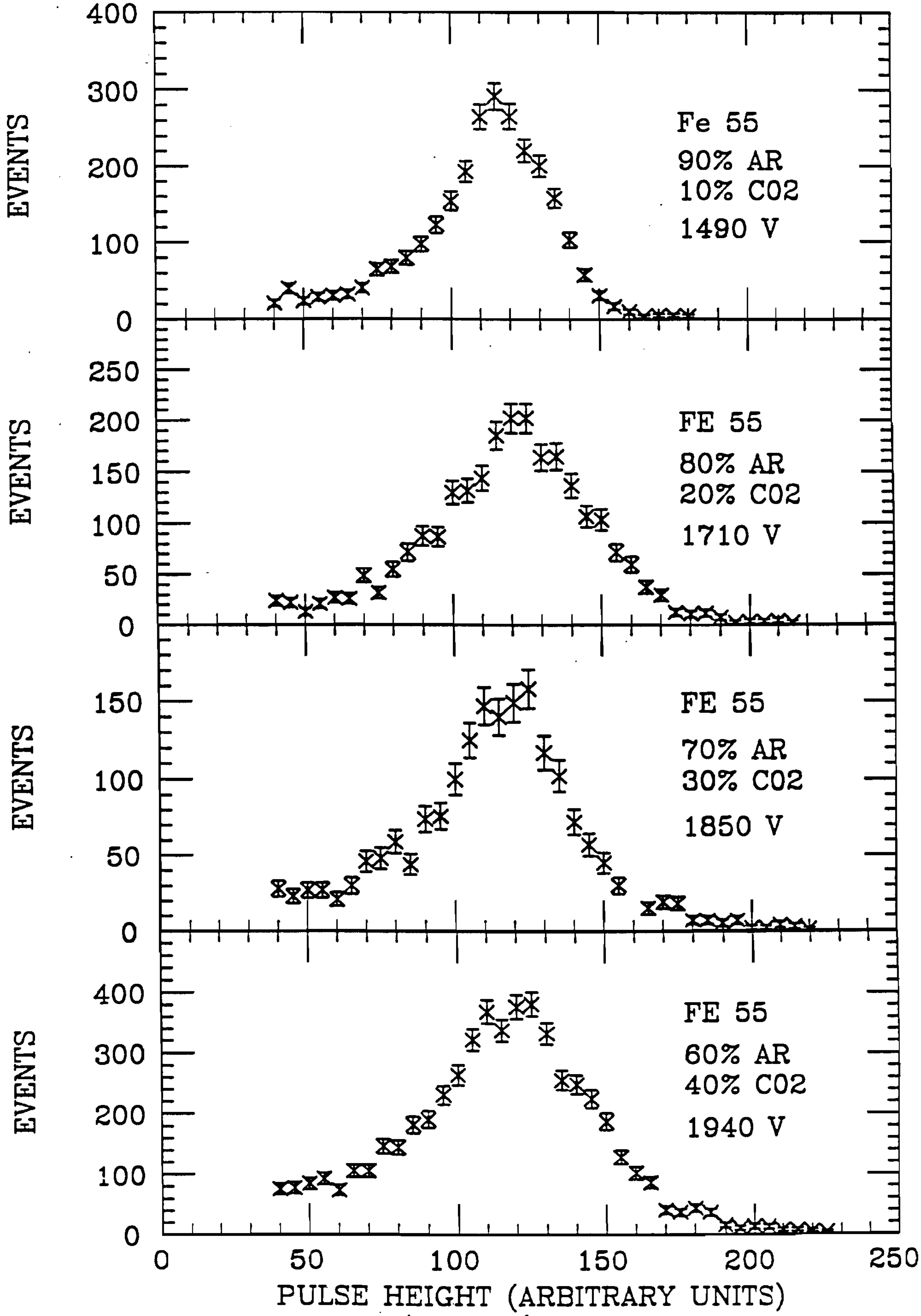

Fe 55
90% AR
10% C02
1490 V
FE 55
80% AR
20% C02
1710 V
FE 55
70% AR
30% C02
1850 V
FE 55
60% AR
40% C02
1940 V
EVENTS
PULSE HEIGHT (ARBITRARY UNITS)

FIG. 2

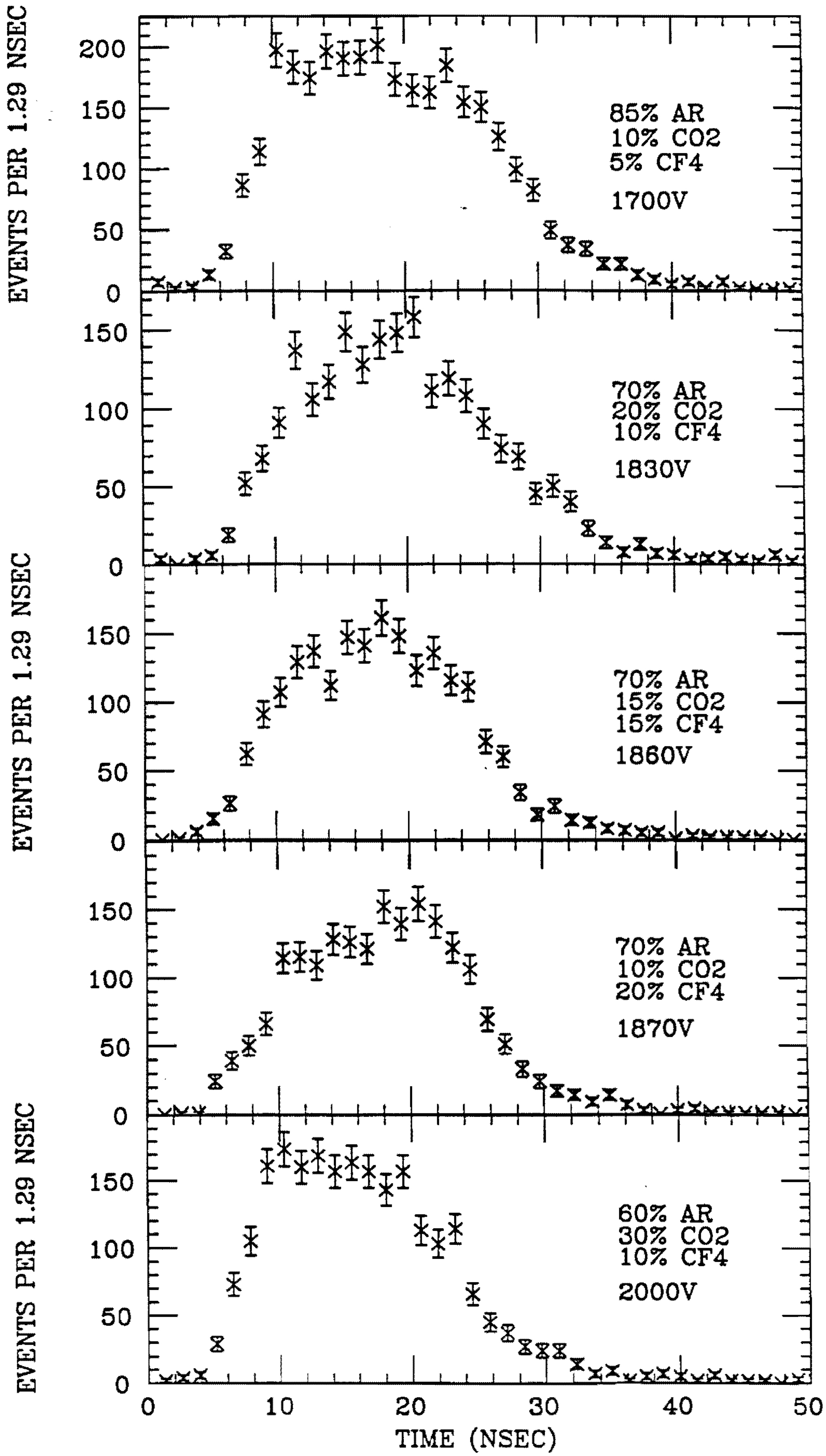

EVENTS PER 1.29 NSEC
200
150
100
50
0
85% AR
10% CO2
5% CF4
1700V
70% AR
20% CO2
10% CF4
1830V
70% AR
15% CO2
15% CF4
1860V
70% AR
10% CO2
20% CF4
1870V
60% AR
30% CO2
10% CF4
2000V
0
10
20
30
40
50
TIME (NSEC)

FIG. 3

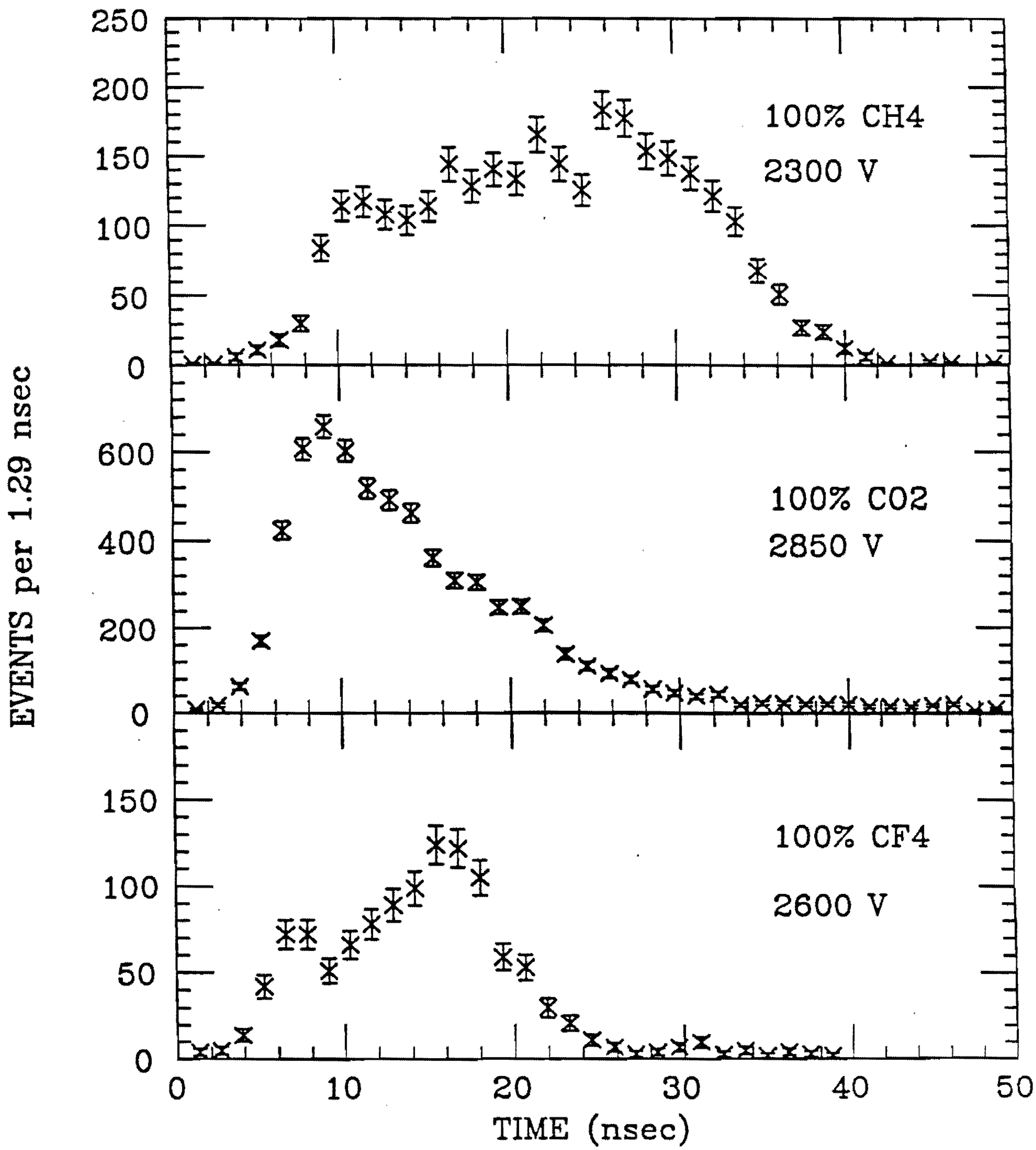
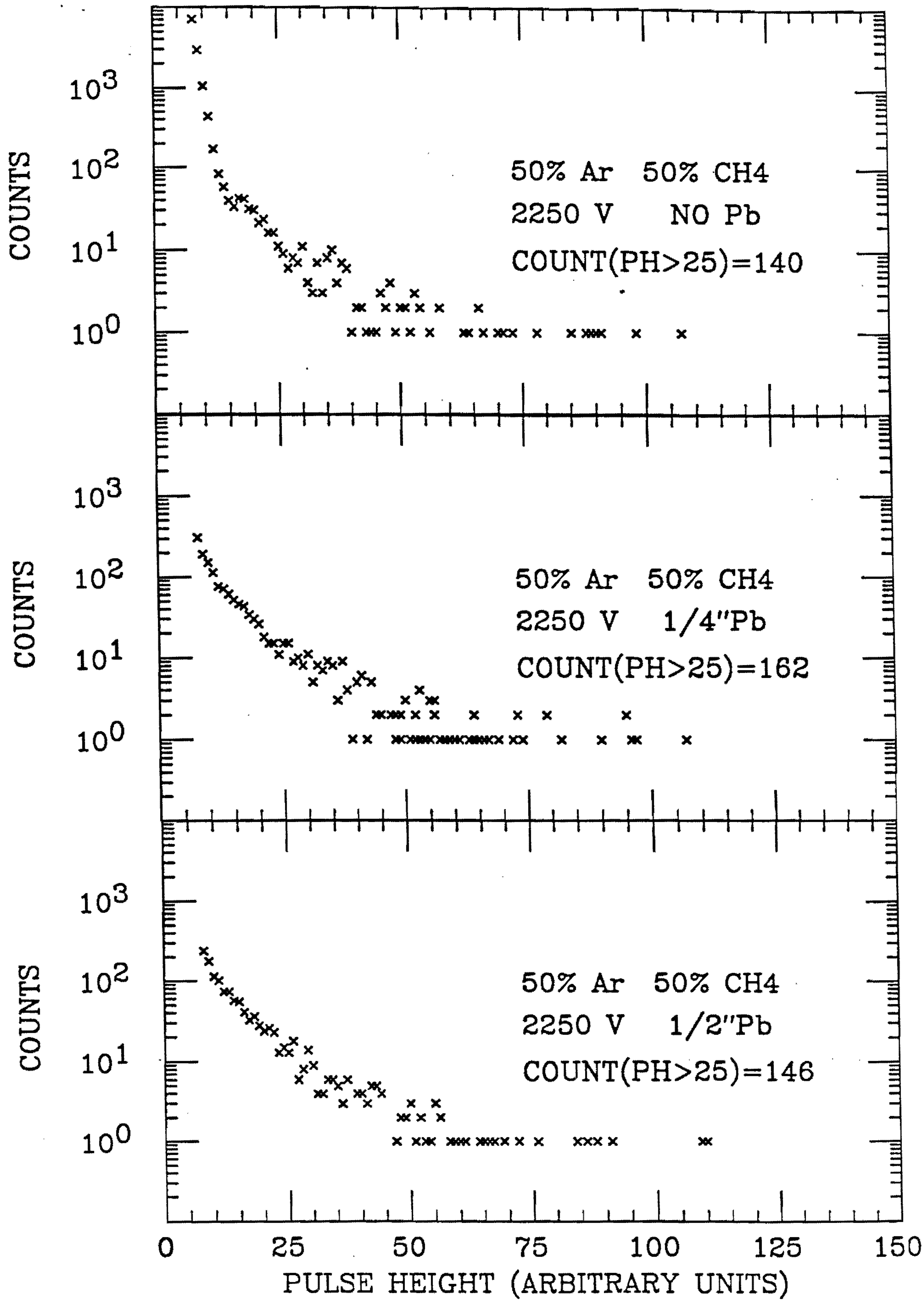
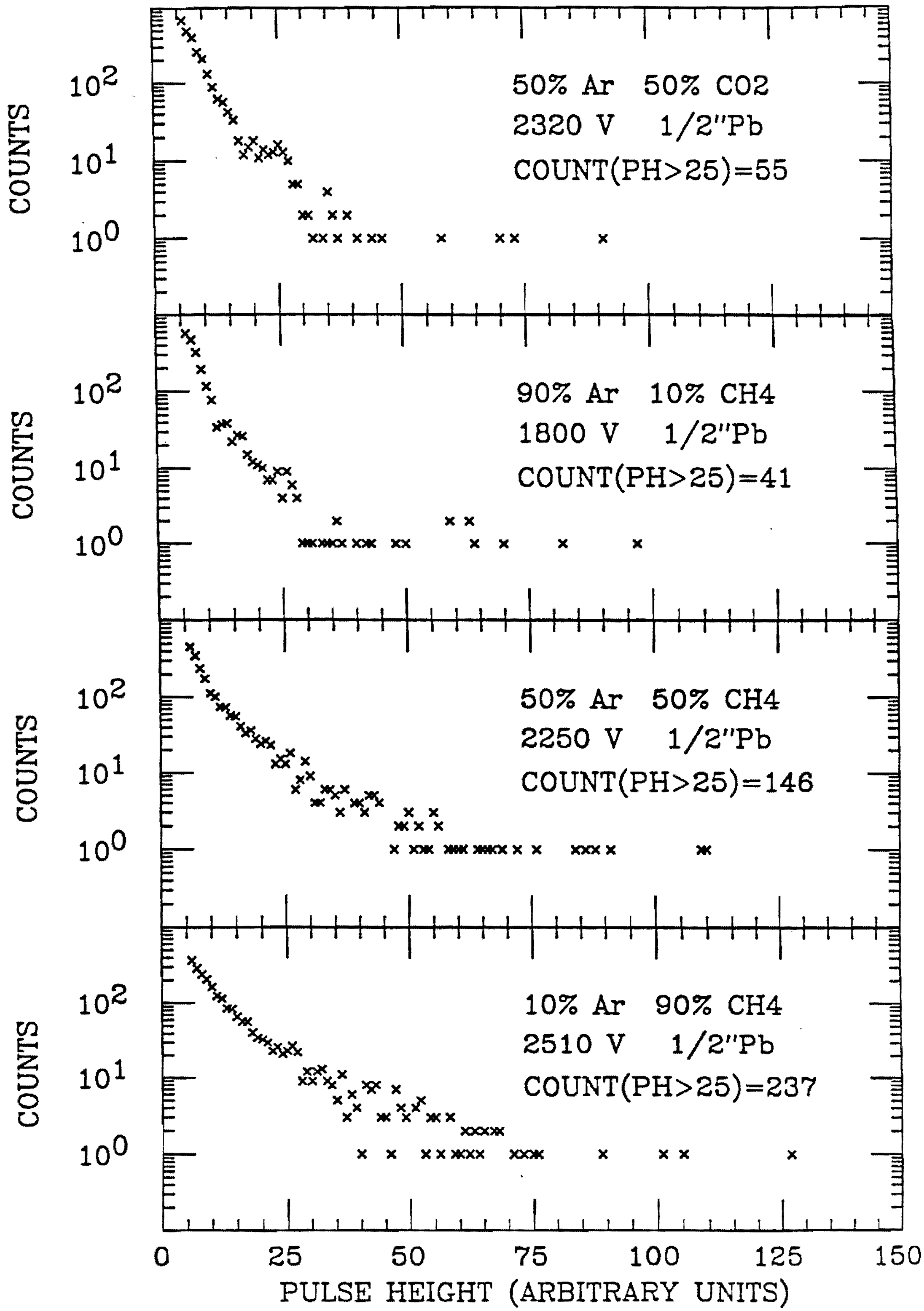

100% CH4
2300 V
100% CO2
2850 V
100% CF4
2600 V
EVENTS per 1.29 nsec
TIME (nsec)
0
50
100
150
200
250
200
400
600
10
20
30
40

FIG. 4



COUNTS
10^3
10^2
10^1
10^0
50% Ar 50% CH4
2250 V NO Pb
COUNT(PH>25)=140
50% Ar 50% CH4
2250 V 1/4"Pb
COUNT(PH>25)=162
50% Ar 50% CH4
2250 V 1/2"Pb
COUNT(PH>25)=146
0
25
50
75
100
125
150
PULSE HEIGHT (ARBITRARY UNITS)

FIG. 5



50% Ar 50% CO2
2320 V 1/2"Pb
COUNT(PH>25)=55
90% Ar 10% CH4
1800 V 1/2"Pb
COUNT(PH>25)=41
50% Ar 50% CH4
2250 V 1/2"Pb
COUNT(PH>25)=146
10% Ar 90% CH4
2510 V 1/2"Pb
COUNT(PH>25)=237
COUNTS
10^2
10^1
10^0
0
25
50
75
100
125
150
PULSE HEIGHT (ARBITRARY UNITS)

FIG. 6

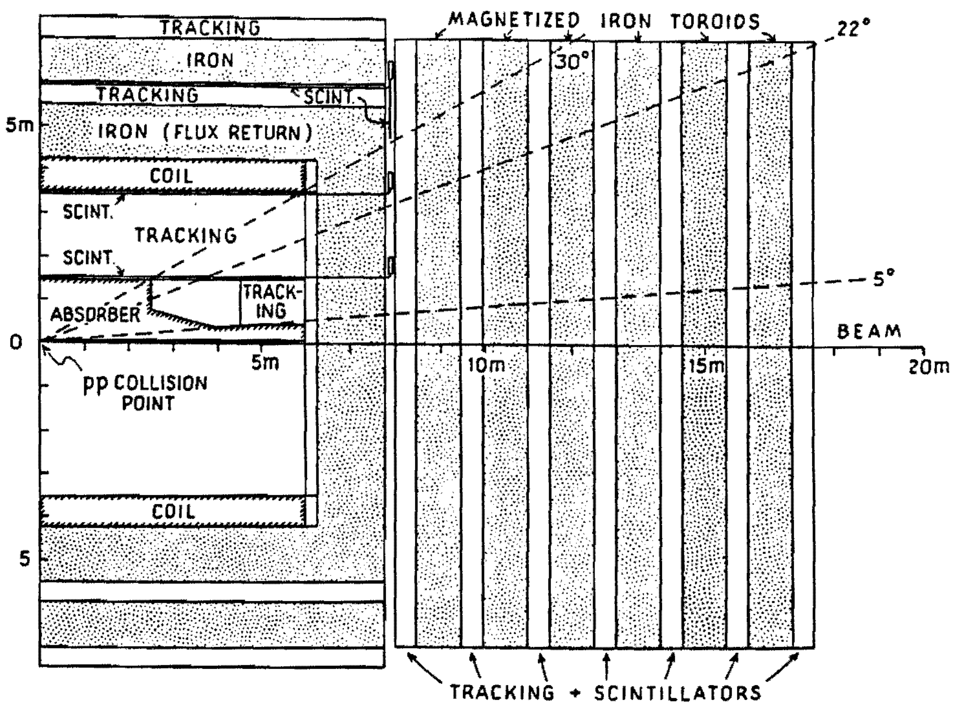


FIG. 7 Side view of muon detector. The detector is symmetric about the collision point and only the right half is shown.

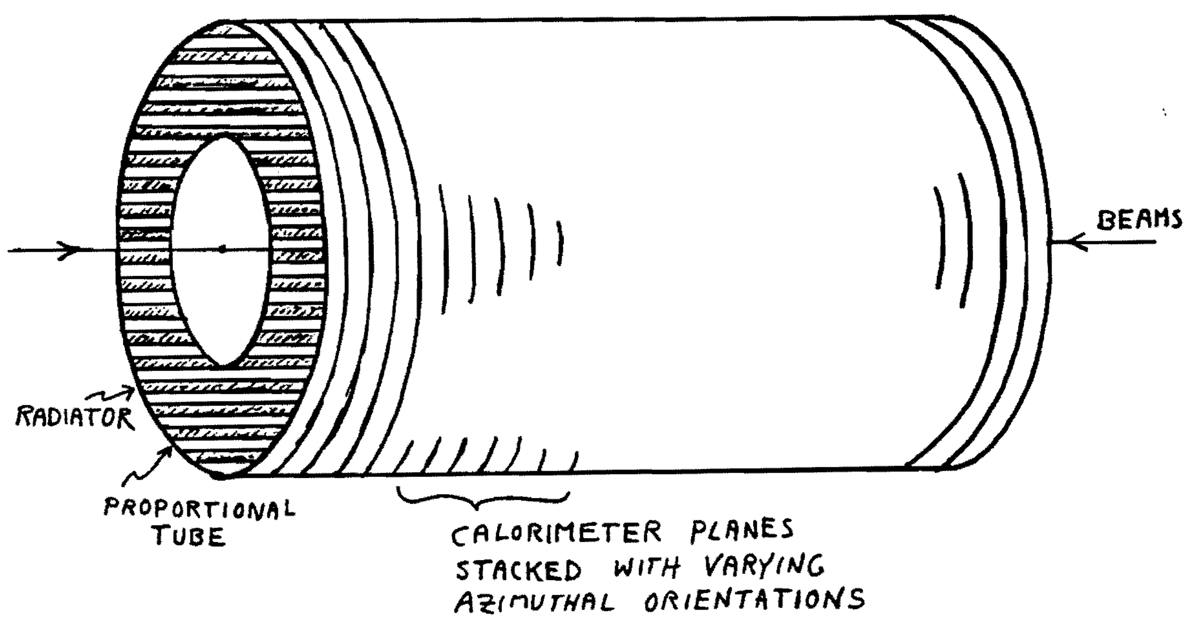
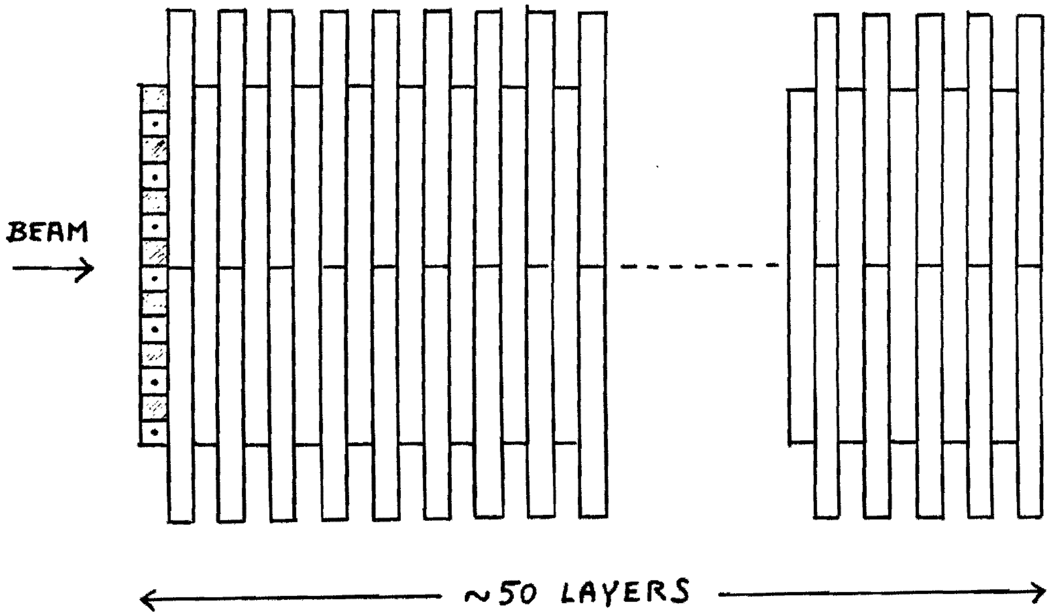


FIG. 8

FIG. 9



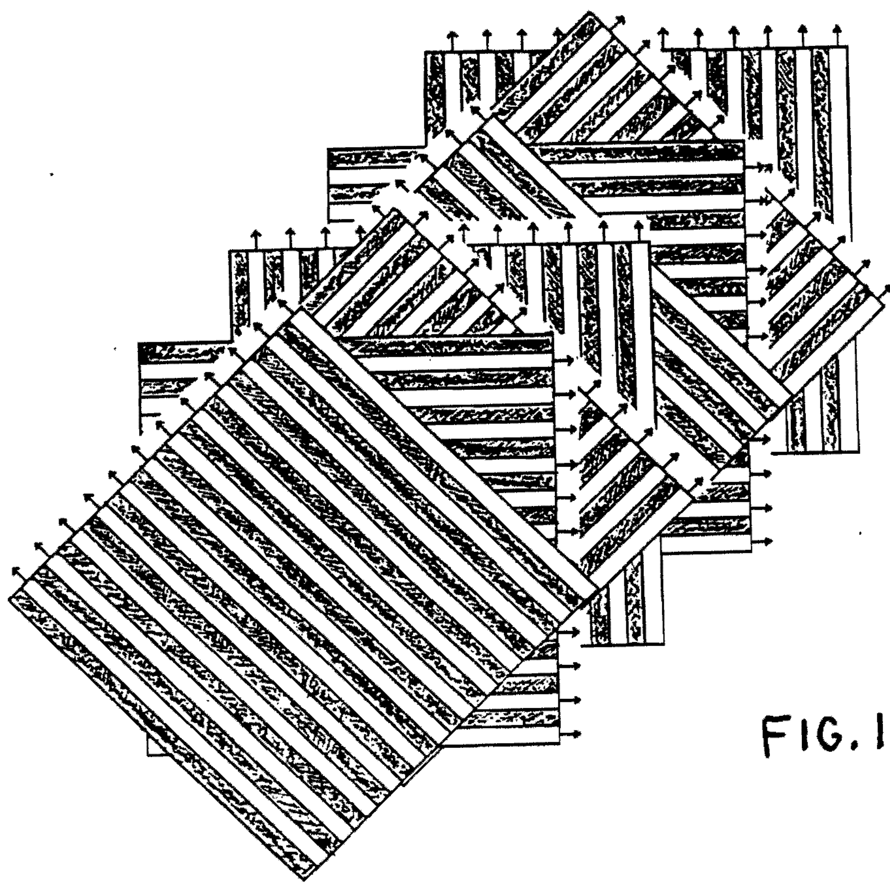


FIG. 10

UM – HE – 88 – 11
April 28, 1988

Tests of Small Proportional Tubes with CF_4 - HRS Gas Mixtures

R. THUN

University of Michigan, Ann Arbor, Michigan 48109

Abstract

We have investigated the operating characteristics and drift times of small proportional tubes (active width = 3.17 mm) containing mixtures of CF_4 and HRS gas (89% Ar, 10% CO_2, 1% CH_4). As the fraction of CF_4 is varied from zero to 100%, maximum drift times decrease from about 32 nsec to 16 nsec. The operating voltage increases and the energy resolution worsens significantly with increases in the CF_4 component.

(submitted to Nuclear Instruments and Methods)

1. INTRODUCTION

The proposed Superconducting Super Collider (SSC) presents a very challenging environment to the designers of experiments.[1] At the expected luminosity of 10^{33} cm^{-2} sec^{-1} the inelastic collision rate is about 10^8 per second with each event generating on average about 100 secondary particles. Three basic problems must be addressed when planning for SSC experiments: rates, radiation damage, and the implementation of suitable triggers. We believe it will be exceedingly important to reduce the spread in signal arrival times within an event down to a level where event pile-up is a manageable problem. Since the average time between events is 10 nsec, it is desirable that the time smearing of signals approach this value.

Proportional wire chamber (PWC) technology has been an essential component of many high energy physics experiments. Indeed, nearly all tracking of charged particles has been done with this versatile detection method. PWCs have also found major application in both electromagnetic and hadronic calorimetry. Such calorimetry will play a central role in most SSC experiments. Wire chambers have a number of properties which make them attractive for SSC detectors. Their application to apparatus with large areas or volumes is comparatively inexpensive and their construction is generally straight-forward. Unlike scintillating or semiconducting materials, wire chambers are rather immune to radiation damage when not powered. This is a potential advantage during SSC machine development and beam manipulations. However, to be suitable as SSC detectors, wire chambers must satisfy certain radiation or "aging" requirements[2] and they must allow fast signal collection times as indicated above. These requirements lead naturally to the consideration of chambers with small cell diameters and the use of gases with high drift velocities.

In our judgement ease of construction is an important factor for detector systems that may contain tens of thousands of proportional cells. This effectively places a lower limit on the cell diameter of about 3 to 4 mm. This follows from the observation that large chamber systems are best operated at atmospheric pressure where the typical number of ionization electrons per mm of track length is about ten. Moreover, the mechanical problems of handling cells much smaller than 3 mm are formidable. Mechanical considerations also lead one to a choice of sense wire diameters that are not too small. Operating voltages increase only slowly with diameter whereas the mechanical strength varies as the square of that dimension. We have found from experience that sense wires with a diameter of 38 μm

give a good compromise between operating characteristics and handling ease. With these factors in mind, we have chosen to test PWCs with an interior cell width of 3.17 mm and with a sense wire diameter of 38 μm.

The choice of proportional counter gas involves a number of considerations. The gas must give a sufficient number of ionization electrons, quench avalanche photons to insure stable operation at reasonable gain, exhibit good "aging" properties and yield high drift velocities for operation at SSC. Regarding this last point, research by others[3–8] has shown that drift velocities above 10 cm/μsec can be obtained with gas mixtures containing carbon tetrafluoride (CF_4). This is about a factor of two higher than the drift velocity in common mixtures of argon and CO_2 or hydrocarbons.

There is one additional consideration regarding the choice of proportional counter gases for SSC detectors and especially SSC calorimeters. Hadronic showers in such calorimeters will lead to a large flux of low-energy ($\sim$ 1 MeV) neutrons which can interact within and outside the calorimeter. Elastic scattering of these neutrons with the protons of any hydrogen component of the PWC gas can result in signals equivalent to those from several hundred minimum-ionizing particles. Such large signals can cause cross-talk problems in tracking chambers or give erroneous energy measurements in calorimeters. For this reason it may be important to minimize or avoid the use of hydrogen in the gas or construction materials of SSC wire chambers.

A gas mixture which minimizes the hydrocarbon content and which has shown good operating characteristics is "HRS gas" consisting by volume of 89% argon, 10% carbon dioxide, and 1% methane.[9] The small amount of methane helps to absorb avalanche photons at wavelengths around 1200 angstrom where carbon dioxide is relatively transparent. Because of its minimal hydrogen content, HRS gas should be rather immune to low-energy neutrons while also being safe to handle in terms of fire hazard.

In this note we report results from tests of small proportional wire tubes operating with mixtures of CF_4 and HRS gas.[10] The CF_4 is a non-flammable, non-toxic gas which increases the drift velocities markedly. The motivation for these tests is the establishment of parameters for the design of possible SSC prototype wire chambers.

2. EXPERIMENTAL SET-UP

The test wire chamber consists of eight identical square brass tubes arranged in a plane as shown in fig. 1. The length of these tubes is 74.6 mm, the outer width is 3.97 mm, and their wall thickness is 0.40 mm. The maximum drift distance for ionization electrons from perpendicularly incident tracks is therefore 1.59 mm. Each tube contains a 38μm diameter gold-plated tungsten wire which is held and centered by a small brass tube inserted into a G-10 fiberglass plug at each end of the chamber tube. Small holes are drilled into the body of each of the eight proportional tubes for gas inlet and outlet and for allowing exposure to an ^{55}Fe X-ray source.

At one end of each tube positive high voltage is transmitted to the sense wire through a 1 MΩ resistor. (The brass body of the chamber is held at ground potential). At the other end signals are taken out via a 100 pF decoupling capacitor. For the purposes of this test all eight tubes were ganged together at both the signal and high voltage ends so that the chamber was operated as a single-channel device.

For measurements of rates and drift times, the signals from the chamber were sent to a LeCroy LD604 amplifier-discriminator chip with an input termination of 100 Ω and a threshold of about 0.4 mV. When measuring pulse height spectra with the ^{55}Fe source, the chamber signal was routed directly to a Quantum 8 pulse height analyzer.[11] Drift time measurements were made with cosmic rays for which the start times were determined with a scintillator placed directly below the chamber as shown in fig. 1. The time interval between the scintillator and chamber signals was converted to a pulse height using a Canberra Model 2043 time analyzer. The output from this time analyzer was then displayed with the Quantum 8 pulse height analyzer.

HRS gas and CF_4 were mixed from separate bottles using flow meters. Care was taken to insure that the total flow of the mixed gas was the same for all mixtures to avoid possible systematic rate-dependent effects when comparing results from different mixtures. This total flow rate was 0.5 cuft/hour.

3. RESULTS

The proportional wire chamber was tested with four gas mixtures consisting of 100% HRS, 20% CF_4 - 80% HRS, 50% CF_4 - 50% HRS, and 100% CF_4 where the percentages are by volume. The first step in testing the chamber was the determination of operating voltages for each of these mixtures. Figure 2 shows the coincidence rate from cosmic rays of the scintillator and chamber signals as a function of chamber voltage. Figure 3 shows the singles rate from just the chamber versus the applied voltage. In this figure a sudden rise of the singles rate is observed at 1500 V for 100% HRS, 1875 V for 20% CF_4 - 80% HRS, 2250 V for 50% CF_4 - 50% HRS, and 2725 V for 100% CF_4. At these voltages the chamber signals become very large and regenerative causing multiple firing of the amplifier-discriminator chip. These voltages are close to the point of spontaneous chamber breakdown. Comparison of figures 2 and 3 indicates that the width of the voltage plateau for good efficiency varies from about 75 V with 100% HRS to about 200 V for 100% CF_4.

The relative gain of the chamber was measured by observing the peak from the 5.89 KeV X ray line of an ^{55}Fe source. This is displayed in fig. 4 as a function of chamber voltage. The peak from this source is clearly resolved in all gas mixtures except for 100% CF_4 for which the ^{55}Fe gives just a very broad, smeared-out distribution. The ^{55}Fe spectra for the other three gas mixtures are shown in fig. 5 at voltages giving similar gain. The resolution clearly worsens with increasing fractions of CF_4, an effect already established in ref. 4.

The drift time distributions from cosmic rays, which illuminate the chamber area uniformly, are shown in fig. 6. The operating voltages indicated in the figure correspond to approximately equal chamber gain for the different gas mixtures. We also recorded drift time distributions at somewhat lower and higher voltages and found the widths of these distributions essentially independent of voltage. The width of the drift time range which encompasses 90% of the chamber signals in each distribution is given to the nearest nsec by:

100% HRS:	32 nsec
20% CF_4 - 80% HRS:	22 nsec
50% CF_4 - 50% HRS:	19 nsec
100% CF_4:	16 nsec

The factor of two decrease in drift times with increasing CF_4 fraction is consistent with the observations in references 3-8.

We note that for uniform illumination of the chamber as in fig. 6, the height of the

drift time distribution at a particular value of the drift time is proportional to the drift velocity at the corresponding position in the cell. As the fraction of CF_4 is increased, one observes a clear asymmetry in the drift time distribution for short and long drift times. The variation in the corresponding drift velocities is roughly a factor of two when the gas is 100% CF_4. When operating the chamber at 2600 V and atmospheric pressure the ratio of electric field to pressure, E/P, varies from about 4.9 V cm^{-1} $torr^{-1}$ at the tube wall to 400 V cm^{-1} $torr^{-1}$ at the sense wire surface.

4. CONCLUSION

Motivated by a desire to find proportional chamber parameters suitable for use at the SSC, we have tested 3.17 mm wide proporational tubes with several mixtures of CF_4 and HRS gas (89% argon, 10% CO_2, 1% CH_4). As the fraction of CF_4 is varied from zero to 100%, the maximum drift times decrease from about 32 to 16 nsec corresponding to average drift velocities of 5.0 to 10 cm/μsec, respectively. HRS gas was chosen for admixture since its low hydrogen content insures fire safety and promises relative immunity to large pulses from interactions with low-energy neutrons. The operating voltage increases and the energy resolution worsens with increases in the CF_4 fraction. Good efficiency was obtained with all gas mixtures. The voltage plateau increases as the CF_4 component increases. A final judgment of the suitability for SSC use of PWCs as tested here requires further systematic studies of rate capabilities and of chamber degradation with radiation exposure.

5. ACKNOWLEDGEMENTS

We appreciate the loan of equipment from C. Akerlof and F. Becchetti. We also acknowledge many useful discussions with J. Kadyk who is conducting systematic chamber aging studies for various gas mixtures including those containing CF_4. Finally, we appreciate the invitation by M. Gilchriese to participate in SSC detector studies. These studies helped motivate this work.

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8. R. Henderson et al., IEEE Trans. on Nucl. Sci. NS-34 (1987) 528.
9. D. Koltick, HRS Internal Memo HRS-197 (1980).
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11. Manufactured by Nucleus, Inc.

FIGURES

1. Schematic of the proportional wire chamber (PWC) and scintillator used for cosmic ray triggers.
2. Coincidence rate from cosmic rays of PWC and scintillator signals as a function of PWC voltage.
3. Singles rate of the PWC as a function of voltage.
4. Measurement of relative gain as a function of voltage using the peak from the 5.89 KeV X-rays of an ^{55}Fe source.
5. Pulse height spectra from ^{55}Fe as measured with the PWC.
6. Drift time distributions from cosmic rays as measured with the PWC for several gas mixtures.

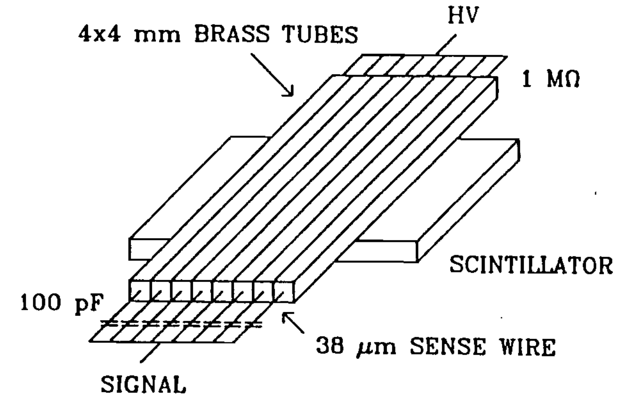

FIG. 1

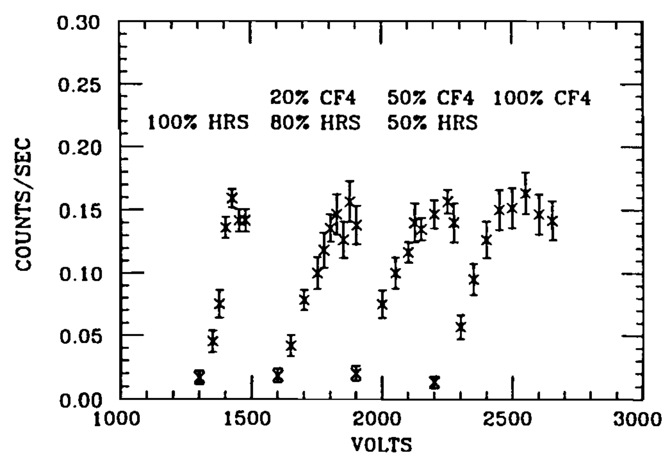

FIG. 2

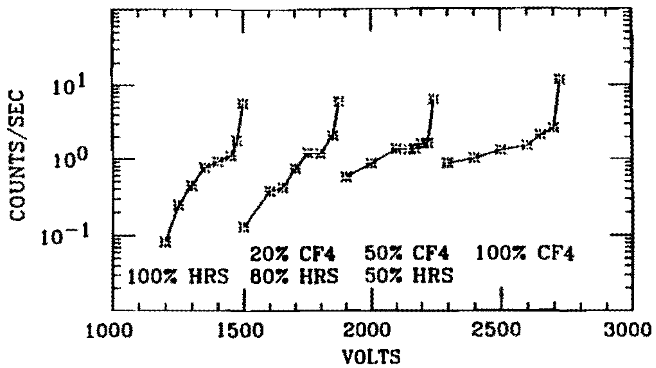

FIG. 3

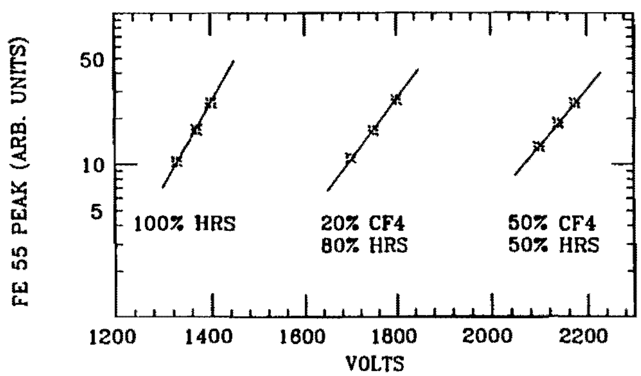

FIG. 4

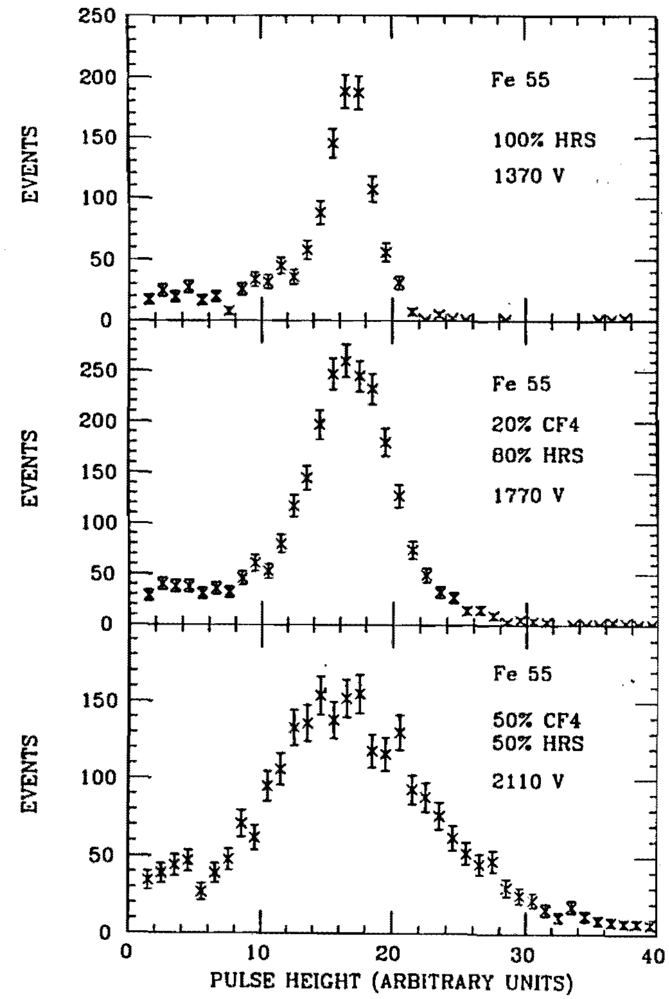

FIG. 5

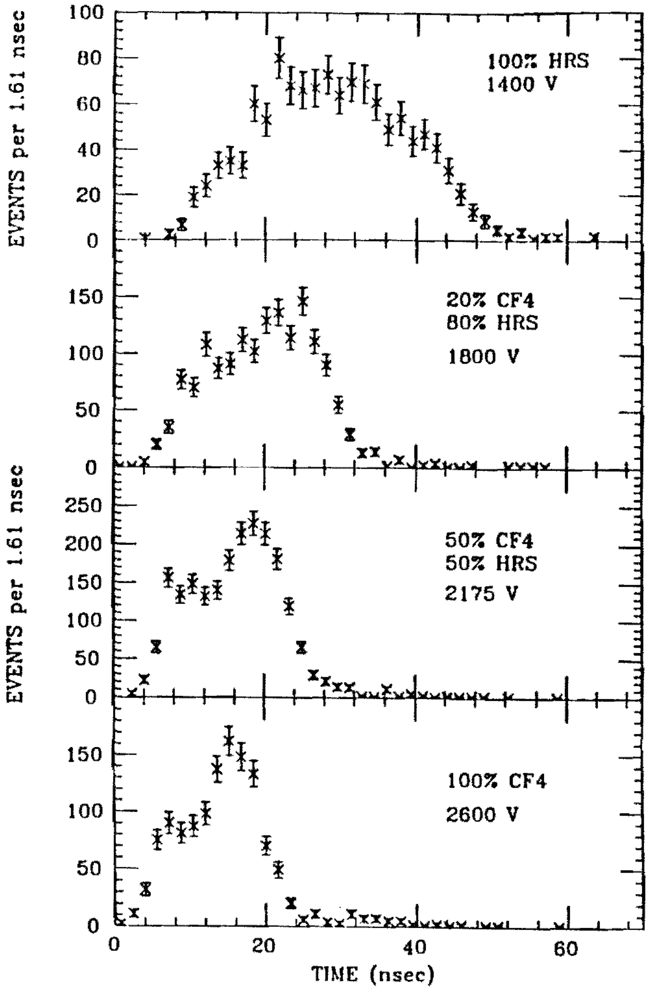
EVENTS per 1.61 nsec
EVENTS per 1.61 nsec
100% HRS
1400 V
20% CF4
80% HRS
1800 V
50% CF4
50% HRS
2175 V
100% CF4
2600 V
TIME (nsec)
0
20
40
60
80
100
50
150
200
250

FIG. 6

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The Harrison M. Randall
Laboratory of Physics

30 August 1988

Leon Lederman
Director
FERMI NATIONAL ACCELERATOR LABORATORY
Batavia, IL 60510

Dear Leon,

A group of us at Michigan are working to develop high-rate fast gas calorimetry and electronics suitable for a high luminosity SSC experiment; a module should be ready to test in about 10 months. We request the use of a FERMILAB testbeam to prove the concepts and implementation.

A copy of our request for Generic SSC Detector R&D Funds is attached. We have developed fast PWC cells for an electromagnetic calorimeter. We intend to use existing electronics to evaluate its performance. We expect to have an ambitious high tech electronics system ready for test somewhat later, and given success would be looking for a high-rate (10**8-10**9) beam to challenge the system.

We are seeking a test beam with 50-200 GeV protons or pions, some component of electrons, and some means to tag them such as a Cerenkov counter. We would request support of a PDP 11 MULTI based data logging system with BISON BOX, CAMAC crate, and magnetic tape or data link to the VAX cluster. We need PREP support mostly at the level needed to instrument and run the beam line, but including a powered NIM bin, 2 scaler modules, a CAMAC ADC module, 8 discriminators, 6 logic functions, and a gate module; the older LeCroy technology would be fine.

We would like to work on the test beam 2 to 6 shifts a week spread over at least a six month period; a control time estimate would be about 200 hours. Our calorimeter module will be on a table such that it can be moved or lowered out of the beam quickly and expeditiously. We would like our part of the CAMAC crate (8 slots) and our NIM bins to be exclusively for us.

Questions can be addressed to R. Thun (313-936-0792) or R. Gustafson (313-936-0812) at the University of Michigan; or by Decnet MICH::THUN or MICH::GUSTAFSON. We are available to help set up/implement the beam line.

Regards,

R. G.
Rudi Thun

Dick Gustafson
Rudi Thun